

Beaming Selection and SN-GRB-Jets Evolution

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Abstract

After a decade of Fireball reign there is a hope for thin collimated Jet to solve the Supernova-GRB mystery

1. Introduction: Ten years of SN-GRB- Jets

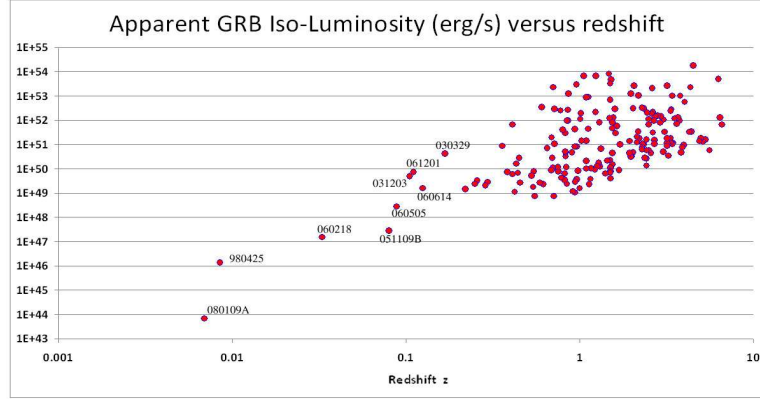


Figure 1. The GRB X-ray luminosity versus redshift updated to 2008 included. The apparent GRB law Luminosity-red-shift evolution in a quadratic power, is mostly due, (in lower regions) to the quadratic distance cut-off and (in higher regions) to the rarer beaming in axis occurring mostly by largest samples and cosmic volumes. The extreme near SN-GRB discover (2-3 sources) imply a huge population of such events (tens of millions at each year) in cosmic distances ($z > 1$), a rate comparable with SN ones: a large fraction of SN do contain a GRB and the Jet persistence and spreading increases the GRB detection

After a decade (since 25 April 08) we know that Supernovas may often (if not always) contain a Jet. However the Luminosity GRB spread is huge and apparently it is evolving just around us. The geometry selection is the cause. Once on line a blazing jet rises as a GRB. The wide apparent GRB power $10^{45} \text{ ergs}^{-1} \leftrightarrow 10^{54} \text{ ergs}^{-1}$ may be explained by comparable SN-power beamed jet collimated within $\frac{\Delta\Omega}{\Omega} \approx 10^{-7} \leftrightarrow 10^{-9}$ thin solid angle. (On the contrary (until now) most popular fireball one-shoot explosion declared a mild cone beam $\frac{\Delta\Omega}{\Omega} \approx 10^{-2} \leftrightarrow 10^{-3}$). Because the rarity to be on axis the most distant (within largest sample) may contain the most collimated and apparently brightest and hardest sources. The inner jet cone are blazing more collimated and their timing variability appear the faster. The nearest GRB would appear as the softer and less powerful ones because by statistical arguments (near distances-small volumes- small samples) are seen mostly off axis at widest cone periphery. Our most updated table of (almost) all GRBs shows the evidence for such *apparent* redshift-Luminosity evolution. The evolution starts from nearest distances (27 Mpc) up to largest redshift. We claim that it is just a selection due to the geometry and due to the detection threshold. The persistent activity of such thin beamed gamma jet may be powered by either a BH (Black Holes) or Pulsars of few Solar Masses. Its activity is longer than the observation and duration of GRB, enlarging the GRB solid angle spread and explaining the *apparent* beaming-probability rarity. Late stages of these jets may be decayed and be suppressed hiding the isotropic SN echoes avoiding easy repetitive GRB signals, even if rare re-brightening took place. Late GRB-SN-Jet may appear (if bent and beamed to us) as a short GRB or a long orphan GRB (depending on jet angular velocity and view angle) because its blazing occurred much later than SN observable signal. XRF are also such off-axis viewing of such late jets. Galactic sources as SGR and AXP, at latest stages and minimal output, may shine in similar ways as GRB. These precessing and spinning γ jet are originated by relativistic electron pairs

(tens-hundred GeV) by Inverse Compton and-or Synchrotron Radiation at pulsars or micro-quasars sources. These Jets are most powerful at Supernova birth. The trembling of the thin jet bent by random magnetic fields near source, explains naturally the observed erratic multi-explosive structure of different GRBs. The jets are often spinning and precessing (by binary companion or inner disk asymmetry) and decaying by power law $\approx \frac{t_o}{t}$ on time scales t_o a few hours; commonly they keep staying inside the observer cone view only a few seconds duration times (GRB); the jet is thinner in gamma and wider in X band by relativistic laws. This explain the wider and longer X GRB (as well as optical) afterglow duration and the otherwise unexplained presences of seldom X-ray precursors. This also explain the rarity (0.5%) of GeV Gamma Burst found only at highest red-shift. The far distance edges ($z_{i,4-6}$) may dilute and hide the GRB-SN isotropic bump signature. The same selection explains the (up to day) absence of GRB hundreds GeV or TeV gamma GRB signals events. Corresponding hundreds GeVs muon neutrinos from GRBs in km^3 mostly correlated with far redshift GRB arrival directions may be too rare to be observed. We suggest the opposite : to follow up the hundred GeV muon neutrino arrival directions with X-ray Telescope in Space to disentangle by X-afterglow eventual hidden gamma burst. In conclusion in our view GRB-SN jet are not the most explosive events in the Universe, but among the most collimated ones.

2. A list of GRB puzzles for Fireball

Why GRBs are so spread in their total energy, (above 8-9 orders of magnitude) and in their peak energy following the so-called Amati correlation[1]? Does the Amati law imply more and more new GRB source families? Why, as shown below the GRB energy is not a constant but a growing function (almost quadratic) of the red-shift?

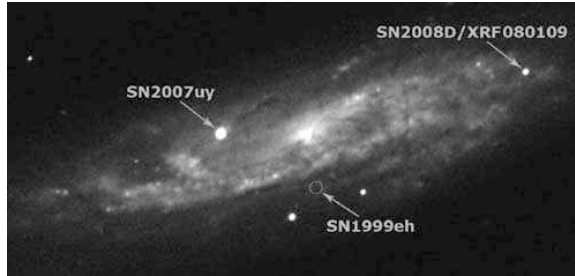


Figure 2. The rare NGC 2770 twice SN within a week time: the XRF080109-SN2008D has deep meaning even for most sceptic theorist

Why are the harder and more variable GRBs ([4, 5]) found at higher redshifts contrary to expected Hubble law? Why does the output power of GRB vary in a range ([5]) of 8-9 orders of magnitudes with the most powerful events residing at the cosmic edges ([6]), see Fig.3? Why has it been possible to find in the local universe (at distances 40-150 Mpc just a part over a million of cosmic space) at least two nearby events (GRB980425 at $z = 0.008$ and recent GRB060218 at $z = 0.03$) while most GRBs should be located at largest volumes, at $z \geq 1$ ([5])? Why are these two nearby GRBs so much under-luminous ([5])? Why are their evolution times so slow and smooth respect cosmic ones? Why do their afterglows show so many bumps and re-brightening as the well-known third nearest event, GRB030329, if they are one-shot explosive event? Indeed why do not many GRB curves show monotonic decay (an obvious consequence of a one-shot explosive event), rather they often show sudden re-brightening or bumpy afterglows

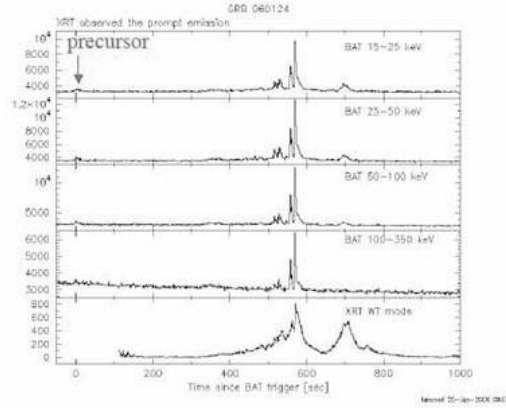


Figure 3. Left: The last GRB070616 long X-ray life: the puzzling ten-minute X-Ray precursor in GRB060124 followed by a huge (apparent) explosive burst (in Fireball model). In our precession model we are in and out an already active persistent Jet axis

at different time scales and wavelengths ([7, 8]) - see e.g. GRB050502B[9]? Why have there been a few GRBs and SGRs whose spectra and time structure are almost identical if their origin is so different (beamed explosion for GRB versus isotropic magnetar)[5, 10]? How can a jetted fireball (with an opening angle of 5° - 10° and solid angle as wide as $0.1sr.$) release an energy-power $10^{50} \text{ ergs}^{-1}$ nearly 6 orders of magnitude more energetic than $10^{44} \text{ ergs}^{-1}$ the corresponding isotropic SN? Why there is not a more democratic energy redistribution (or energy equipartition). How Fireball Jet Model may fine tune multi-shells around a GRB in order to produce tuned shock explosions and re-brightening with no opacity within minutes, hours, days time-distances from the source([8])? How can some ($\sim 6\%$) of the GRBs (or a few SGRs) survive the "tiny" (but still extremely powerful) pre-explosion of its *precursor* without any consequences for the source, and then explode catastrophically few minutes later? In such a scenario, how could the very recent GRB060124 (at redshift $z = 2.3$) be preceded by a 10 minutes precursor, and then being able to produce multiple bursts hundreds of times brighter? Why is the short GRB050724 able to bump and re-bright a day after the main burst[11]? In this connection why are the GRB021004 light curves (from X to radio) calling for an early and late energy injection? Why rarest and historical GRB940217, highest energetic event, could held more than 5000s long.?

Once these major questions are addressed and (in our opinion) mostly solved by our precessing gamma jet model, a final question still remains, calling for a radical assumption on the thin precessing gamma jet: how can an ultra-relativistic electron beam (in any kind of Jet models) survive the SN background and dense matter layers and escape in the outer space while remaining collimated? Such questions are ignored in most Fireball models that try to fit the very different GRB afterglow light curves with shock waves on tuned shells and polynomial ad-hoc curves around the GRB event. Their solution forces us more and more toward a unified precessing Gamma Jet model fed by the PeV-TeV lepton showering (about UHE showering beam see analogous ones[13, 14]) into γ discussed below. As we will show, the thin gamma precessing jet is indeed made by a chain of primary processes (PeV muon pair bundles decaying into electrons and then radiating via synchrotron radiation), requiring an inner ultra-relativistic jet inside the source.

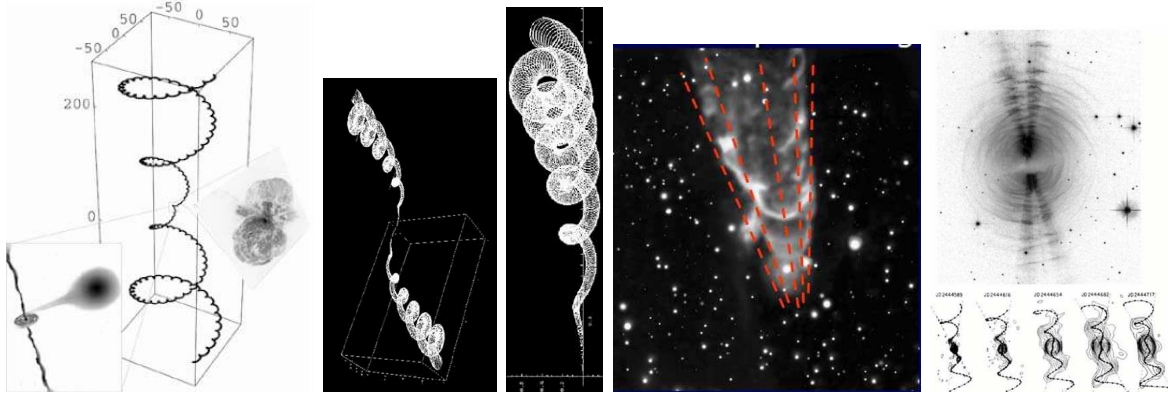


Figure 4. From the left to the right: A possible 3D structure view of the precessing jet obtained with a precessing and spinning, gamma jet; at its center the "explosive" SN-like source for a GRB (or a steady binary system, like Eta-Carina, for a SGRs) where an accretion disc around a compact object, powers a thin collimated precessing jet. In the two center figures, the 3D and the projected 2D of such similar precessing Jet. In the right fourth panel we show an Herbig Haro-like object HH49, whose spiral jets are describing, in our opinion, at a lower energy scale, such precessing Jets . Finally the well known micro-quasars SS-433, its radio evolution spirals in lowest right figure; over it stands the egg-nebula shape suggesting a similar inner conical section of a twin precessing Jet

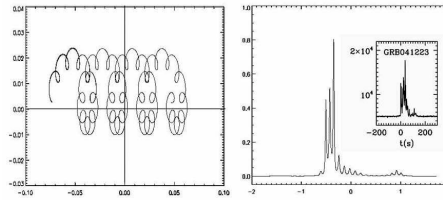


Figure 5. The possible simple beam track of a precessing jet to observer located at origin. On the left, observer stays in (0.00 ; 0.00); the progenitor electron pair jet (leading by IC[3] to a gamma jet) has here a Lorentz factor of a thousand and consequent solid angle at $\sim \mu$ sr. Its consequent blazing light curve corresponding to such a similar outcome observed in GRB041223.

3. Blazing Spinning and Precessing jets in GRBs

The huge GRBs luminosity (up to 10^{54} erg s^{-1}) may be due to a high collimated on-axis blazing jet, powered by a Supernova output; the gamma jet is made by relativistic synchrotron radiation and the inner the jet the harder and the denser is its output. The harder the photon energy, the thinner is the jet opening angle. The hardest and shortest core Gamma event occur at maximal apparent luminosity once the jet is beamed in inner axis. The jets whole lifetime, while decaying in output, could survive as long as thousands of years, linking huge GRB-SN jet apparent Luminosity to more modest SGR relic Jets (at corresponding X-Ray pulsar output). Therefore long-life SGR (linked to anomalous X-ray AXPs) may be repeating; if they are around our galaxy they might be observed again as the few known ones and the few rare

extragalactic XRFs. The orientation of the beam respect to the line of sight plays a key role in differentiating the wide GRB morphology. The relativistic cone is as small as the inverse of the electron progenitor Lorentz factor. To observe the inner beamed GRB events, one needs the widest SN sample and the largest cosmic volumes. Therefore the most far away are usually the brightest. On the contrary, the nearest ones, within tens Mpc distances, are mostly observable on the cone jet *periphery*, a bit off-axis. Their consequent large impact crossing angle leads to longest *anomalous* SN-GRB duration, with lowest fluency and the softest spectra, as in earliest GRB98425 and in particular recent GRB060218 signature. A majority of GRB jet blazing much later (weeks, months after their SN) may hide their progenitor explosive after-glow and therefore they are called *orphan* GRB. Conical shape of few nebulae and the precessing jet of few known micro-quasar, describe in space the model signature. Recent outstanding episode of X-ray precursor, ten minutes before the main GRB event, cannot be understood otherwise.

In our model to make GRB-SN in nearly energy equipartition the jet must be very collimated $\frac{\Omega}{\Delta\Omega} \simeq 10^8\text{-}10^{10}$ ([15, 5, 16]) explaining why apparent (but beamed) GRB luminosity $\dot{E}_{GR-jet} \simeq 10^{53}\text{-}10^{54} \text{ erg s}^{-1}$ coexist on the same place and similar epochs with lower (isotropic) SN powers $\dot{E}_{SN} \simeq 10^{44} - 10^{45} \text{ erg s}^{-1}$. In order to fit the statistics between GRB-SN rates, the jet must have a decaying activity ($\dot{L} \simeq (\frac{t}{t_o})^{-\alpha}$, $\alpha \simeq 1$): it must survive not just for the observed GRB duration but for a much longer timescale t_o , possibly thousands of time longer observed GRB signal $t_o \simeq 10^4 \text{ s}$. The much late stages of the GRBs (within the same decaying power law) would appear as a SGRs: indeed the same law for GRB output at late time (thousand years) is still valid for SGRs active at X-ray pulsar Luminosity. SGRs are not Magnetar fire-ball explosion but blazing jets with lower power (than GRB) but also much nearer distances.

4. The puzzle of a huge SGR1806-20 flare and the GRB-SGR connection

The SGR are also puzzling (within explosive Magnetar model). Why SGR1806-20 of 2004 Dec. 27th, shows no evidence of the loss of its period P or its derivative \dot{P} after the huge *Magnetar* eruption, while in this model its hypothetical magnetic energy reservoir (linearly proportional to $P \cdot \dot{P}$) must be largely exhausted? Why do SGR1806 radio afterglows show after its huge eruption 2004 a mysterious two-bump radio curve implying additional energy injection many days later? Why its wide polarization change took place in days after the explosion. A precessing thin jet may explain all the puzzles. Why has the SGR1806-20 polarization curve been changing angle radically in short (\sim days) timescale? Indeed the puzzle (for one shot popular Magnetar-Fireball model[18]) arises for the surprising giant flare from SGR 1806-20 that occurred on 2004 December 27th: if it has been radiated isotropically (as assumed by the Magnetar model[18]), most of - if not all - the magnetic energy stored in the neutron star NS, should have been consumed at once. This should have been reflected into sudden angular velocity loss (and-or its derivative) which was *never observed*. On the contrary a thin collimated precessing jet $\dot{E}_{SGR-jet} \simeq 10^{36}\text{-}10^{38} \text{ erg s}^{-1}$, blazing on-axis, may be the source of such an apparently (the inverse of the solid beam angle $\frac{\Omega}{\Delta\Omega} \simeq 10^8\text{-}10^9$) huge bursts $\dot{E}_{SGR-Flare} \simeq 10^{38} \cdot \frac{\Omega}{\Delta\Omega} \simeq 10^{47} \text{ erg s}^{-1}$ with a moderate steady jet output power (X-Pulsar, SS433). This explains the absence of any variation in the SGR1806-20 period and its time derivative, contrary to any obvious correlation with the dipole energy loss law.

In our model, the temporal evolution of the angle between the spinning (PSRs), precessing (binary, nutating) jet direction and the rotational axis of the NS, can be expressed as

$$\theta_1(t) = \sqrt{\theta_x^2 + \theta_y^2}$$

where

$$\begin{aligned}\theta_y(t) = & \theta_a \cdot \sin \omega_0 t + \cos(\omega_b t + \phi_b) + \theta_{psr} \cdot \cos(\omega_{psr} t + \phi_{psr}) \cdot |(\sin(\omega_N t + \phi_N))| + \\ & + \theta_s \cdot \cos(\omega_s t + \phi_s) + \theta_N \cdot \cos(\omega_N t + \phi_N)) + \theta_y(0)\end{aligned}$$

and a similar law express the $\theta_x(t)$ evolution. The angular velocities and phase labels are self-explained[16, 17]. Lorentz factor γ of the jet's relativistic particles, for the most powerful SGR1806-20 event, and other parameters adopted for the jet model represented in Fig. 4 are shown in ([16, 17]).

The simplest way to produce the γ emission would be by IC of GeVs electron pairs onto thermal infra-red photons. Also electromagnetic showering of PeV electron pairs by synchrotron emission in galactic fields, (e^\pm from muon decay) may be the progenitor of the γ blazing jet. However, the main difficulty for a jet of GeV electrons is that their propagation through the SN radiation field is highly suppressed. UHE muons ($E_\mu \geq \text{PeV}$) instead are characterized by a longer interaction length either with the circum-stellar matter and the radiation field, thus they have the advantage to avoid the opacity of the star and escape the dense GRB-SN isotropic radiation field [16, 17]. We propose that also the emission of SGRs is due to a primary hadronic jet producing ultra relativistic e^\pm (1 - 10 PeV) from hundreds PeV pions, $\pi \rightarrow \mu \rightarrow e$, (as well as EeV neutron decay in flight): primary protons can be accelerated by the large magnetic field of the NS up to EeV energy. The protons could in principle emit directly soft gamma rays via synchrotron radiation with the galactic magnetic field ($E_\gamma^p \simeq 10(E_p/\text{EeV})^2(B/2.5 \cdot 10^{-6} \text{ G}) \text{ keV}$), but the efficiency is poor because of the too small proton cross-section, too long timescale of proton synchrotron interactions. By interacting with the local galactic magnetic field relativistic pair electrons lose energy via synchrotron radiation: $E_\gamma^{sync} \simeq 4.2 \cdot 10^6 (\frac{E_e}{5 \cdot 10^{15} \text{ eV}})^2 (\frac{B}{2.5 \cdot 10^{-6} \text{ G}}) \text{ eV}$ with a characteristic timescale $t^{sync} \simeq 1.3 \cdot 10^{10} (\frac{E_e}{5 \cdot 10^{15} \text{ eV}})^{-1} (\frac{B}{2.5 \cdot 10^{-6} \text{ G}})^{-2} \text{ s}$. This mechanism would produce a few hundreds keV radiation as it is observed in the intense γ -ray flare from SGR 1806-20.

The Larmor radius is about two orders of magnitude smaller than the synchrotron interaction length and this may imply that the aperture of the showering jet is spread in a fan structure [13, 14] by the magnetic field, $\frac{R_L}{c} \simeq 4.1 \cdot 10^8 (\frac{E_e}{5 \cdot 10^{15} \text{ eV}}) (\frac{B}{2.5 \cdot 10^{-6} \text{ G}})^{-1} \text{ s}$. Therefore the solid angle is here the inverse of the Lorentz factor ($\sim \text{nsr}$). In particular a thin ($\Delta\Omega \simeq 10^{-9}$ - 10^{-10} sr) precessing jet from a pulsar may naturally explain the negligible variation of the spin frequency $\nu = 1/P$ after the giant flare ($\Delta\nu < 10^{-5} \text{ Hz}$). Indeed it seems quite unlucky that a huge ($E_{Flare} \simeq 5 \cdot 10^{46} \text{ erg}$) explosive event, as the needed mini-fireball by a magnetar model[18], is not leaving any trace in the rotational energy of the SGR 1806-20, $E_{rot} = \frac{1}{2} I_{NS} \omega^2 \simeq 3.6 \cdot 10^{44} (\frac{P}{7.5 \text{ s}})^{-2} (\frac{I_{NS}}{10^{45} \text{ g cm}^2}) \text{ erg}$. The consequent fraction of energy lost after the flare is severely bounded by observations: $\frac{\Delta(E_{Rot})}{E_{Flare}} \leq 10^{-6}$. More absurd in Magnetar-explosive model is the evidence of a brief precursor event (one-second SN output) taking place with no disturbance on SGR1806-20 *two minutes before* the hugest flare of 2004 Dec. 27th. The thin precessing Jet while being extremely collimated (solid angle $\frac{\Omega}{\Delta\Omega} \simeq 10^8$ - 10^{10} ([15, 5, 16, 17]) may blaze at different angles within a wide energy range (inverse of $\frac{\Omega}{\Delta\Omega} \simeq 10^8$ - 10^{10}). The output power may exceed $\simeq 10^8$, explaining the extreme low observed output in GRB980425 -an off-axis event-, the long late off-axis gamma tail by GRB060218[19]), respect to the on-axis and more distant GRB990123 (as well as GRB050904).

5. Conclusion: Hundred GeVs γ , ν_μ and PeVs ν_τ precursors

The GRBs are not the most powerful explosions, but just the most collimated ones. Their birth rate is comparable to the SN ones (a few a second in the observable Universe), but their thin beaming (10^{-8} sr) make them extremely rare ($10^{-8}s^{-1}$) rate to point to us at their very birth. The persistent precessing (slow decay of scale time of hours) and moving beam span a wider angle with time and it encompass a larger solid angle increasing the rate by 3 order of magnitude to observed GRB rate; after a few hours $\simeq 10^4s$. the beam may hit the Earth and appear as a GRB near coincident with a SN. The power law decay mode of the jet make it alive at smaller power days, months and year later, observable only at nearer and middle distance as a Short GRB or (at its jet periphery) as an XRF or in our galaxy as a SGRs. The presence of a huge population of active jets fit a wide spectrum of GRB morphology [21]. Now in our Universe thousands of GRBs are shining at SN peak power, but pointing else where. Only one a day might be blazing to us and captured at SWIFT threshold level. Thousand of billions are blazing (unobserved) as SGRs in the Universe. Short GRBs as well SGRs are born in SNRs location and might be revealed in nearby spaces. The GRB-SGRs connection with XRay-Pulsars make a possible link to AXRay pulsar jets recently observed in most X-gamma sources as the famous Crab. The possible GRB-SGR link to X-gamma pulsar is a natural possibility to be considered as a grand unification of the model. Our prediction is that a lower threshold, as GLAST-Fermi satellite will induce a higher rate of GRBs both at nearer volumes (as GRB060218 and GRB 980425) and at largest red-shifts. Rarest hard GeV γ at TeV are too far and opaque by IR cut-off. Rarer Tens GeV neutrino GRB muons may trace in Km^3 detector the direction of such far GRB whose prompt X-ray afterglow maybe followed up. In analogy up-ward tens PeVs Tau air-shower may trigger the prompt X-Ray telescope searching afterglows of far hidden GRBs. Their discovery will confirm the PeV-SN-GRB-Jet model.

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